

THE GOVERNOR'S REPORT

The Potential for

DROUGHT IN MONTANA

May 2007

The Honorable Governor Brian Schweitzer

Prepared by

The Montana Drought Advisory Committee

www.Drought.mt.gov

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EXECUTIVE SUMMARY

Each spring, the Montana Governor's Drought Advisory Committee presents a report to the Governor on the potential for drought for the coming growing and water use season. The *Governor's Report on the Potential for Drought 2007* summarizes water supply and moisture conditions and provides the reader with projections prepared by the Committee's member agencies on what Montanans can expect through early summer for reservoir storage, streamflow, soil moisture, and wildfire. At this time it is likely that water uses dependent on snow water from the annual mountain snowpack will face **Moderate hydrological drought** impacts this summer. Impacts from the *agricultural, meteorological, and socio-economic* aspects of drought are expected to be low through June.

Water supply and moisture condition experts on the Governor's Drought Advisory Committee are confirming that Montanans are facing the prospect of water shortages in 2007 as a result of the mountain snowpack across the state ending the snow water content accumulation season, about April 15, at only 75 percent of average and lower in some basins. According to the Natural Resources Conservation Service (NRCS), two warm spells in early May caused the snowpack to lose a total of 20 to 50 percent of its snow water content leaving many basins with only 30 to 50 percent of the average snow water content by the third week of May.

The shortfall in available snow water translates directly into below average streamflow and reservoir inflow in coming months that will likely present hardship to water users by mid-summer even if the state receives average precipitation between now and then. According to the U.S. Geological Survey (USGS) it now appears that most rivers and streams reached peak spring runoff flow by the second to third week of May, two to three weeks earlier than normal. Only with above average precipitation and temperatures in the average to cooler than average range, can we expect to see manageable hydrological drought impacts in 2007. It is important to remember that low streamflow, wildfire, and other impacts from dry and warm weather are not uncommon by late summer in Montana in any given year.

The committee is in agreement at this time that Montana can expect surface water shortages by summer without well above average precipitation on a regular basis to augment streamflow as the state enters the heavy water use and low flow season from mid-July through September. The potential for drought in other critical economic sectors, such as dryland farming however, looks less likely at this time, although agricultural drought has a shorter onset timeframe than hydrological drought and can occur within days during hot spells. Following measured recovery from drought conditions in early 2006 it appears that generally-speaking, the potential for drought impacts to Montana in 2007 is *Moderate*, particularly for surface water.

The official Internet site of the Governor's Drought Advisory Committee can be found at: www.drought.mt.gov . Presentations of the Committee's meetings are posted on the site at "Committee" and then "Meeting Information."

INTRODUCTION

The Montana Governor's Drought Advisory Committee (Committee) is charged with monitoring, forecasting, and reporting water supply and moisture conditions, enabling Montanans to make timely and informed decisions to mitigate drought impacts in a proactive manner. The Committee meets most months from March through October to provide Montanans with regular drought updates and projections. Additionally, an assessment subcommittee meets monthly year around to assess and report water supply and moisture conditions.

Members from the subcommittee participate in a national weekly discussion as well to contribute an assessment of drought conditions in Montana for the composition of the U.S. Drought Monitor Map and its related suite of products. See: <http://drought.unl.edu/dm/monitor.html>
The Committee met May 23 to learn from its reporters that drought conditions improved in 19 counties and worsened in only two counties since April. All of the state's counties are currently in either the No Drought or Slightly Dry categories on the draft May Status map.

Preparing an outlook for the potential for drought each spring involves assessing components of the water supply and moisture condition picture in spring, including the water content of the mountain snowpack, existing reservoir storage levels, soil moisture, and pre-runoff streamflow levels. From these data, member agencies, such as the USDA's Natural Resources Conservation Service (NRCS), which monitors snow water content of the mountain snowpack, can begin to develop streamflow forecasts for coming months and express forecasts using map products such as the SWSI (Surface Water Supply Index).

The Committee's state agency members are charged with making the best use of the information reported by the Committee's monitoring member agencies in preparation for the start of the water use, or growing season. Outlooks are also critical to the informed management of the state's natural resources such as its fisheries and state and federal wildlife management lands, recreation areas and other multiple use lands prone to wildfire as the dry season approaches.

CURRENT WATER SUPPLY AND MOISTURE CONDITIONS

Montana Drought Status by County

The Montana Governor's Drought Advisory Committee developed and implemented a new drought severity classification system in 2004 and in 2005, the committee began performing the monthly assessment by county on a year around basis. A technical group, comprised of water supply and moisture experts from the Committee assesses conditions for each county using a variety of moisture and water supply indices and field reports from county extension agents and state and federal field offices. Committee staff facilitates the assessment by county exercise.

The group classifies each county in one of six descriptive categories ranging from "*No Drought – Moist*" to "*Extremely Dry*." Other categories include *No Drought*, *Slightly Dry*, *Moderately Dry*, and *Severely Dry*. The Montana Drought Status Map legend also notes that the status categories, Moderately Dry and Severely Dry (and worse), correspond with the "*Drought Alert*" and "*Severe Drought*" action levels used in the Montana Drought Plan. The plan includes specific actions for the two threshold levels that specify actions for state, federal, and local government to take so mitigation can occur in a timely manner. See: <http://nris.state.mt.us/Drought/status/>

The April 2007 Montana Drought Status by County Map, indicated that conditions continued to improve east of the Divide while all but two counties west of the Divide slipped one category. Statewide, 26 counties were found to be within the No Drought category, up from 22 in March; 21 counties were rated as Slightly Dry, up from 16 in March; and nine counties were ranked as Moderately Dry, down from 14 in March. There were no counties rated as Severely Dry in April in contrast to March when four counties were rated as such.

The Committee again convened May 23 and concluded that generous amounts of valley and mountain precipitation for the months of April and May left all counties of the state rated as either No Drought (34) or Slightly Dry (22). The subcommittee noted however, that the shortfall in snow water content of mountain snowpack this winter and spring over most of the state, although not a significant factor presently with streamflow runoff within an acceptable range, was likely to present water shortages as summer approaches as illustrated by the May 1, 2007 SWSI Map. See: http://nris.mt.gov/Nrcs/May07/swsi05_07.pdf

Mountain Precipitation

Most of the annual streamflow in Montana originates as snowfall that accumulates high in the mountains during fall, winter, and spring. Aquifers, lakes, streams, and reservoirs are largely dependent on runoff from mountain snowpack. As the snow pack accumulates, hydrologists forecast the runoff that will occur when it melts, and in turn, streamflow for the summer months. Montana's mountain snowpack generally accounts for 80 percent of streamflow in spring and early summer in Montana's higher elevation river valleys. The mountain elevation NRCS Snotel gauging network is comprised of over 100 fully automated sites that record total precipitation and snow water content of current snowpack across the state each day of the water year.

The annual peak of snow water content of the mountain snowpack occurs in mid-April each year, according to the USDA Natural Resources Conservation Service (NRCS) See: Table 1. Peak Water Content of Mountain Snowpack in Montana – Water Year to April 16, 2007.

Table 1 Remaining Water Content of Mountain Snowpack in Montana and Water Year-to-Date Precipitation ⁽¹⁾		
Based on Mountain Data from NRCS SNOTEL Sites As of Monday, April 16, 2007		
Basin	Water Year Snow Water Equivalents ⁽²⁾ (% of average) ⁽³⁾	Water Year-to-Date ⁽⁴⁾ Precipitation (% of average)
Kootenai River	86	114
Flathead River	77	100
Upper Clark Fork River	76	95
Bitterroot River	67	95
Lower Clark Fork River	72	103
Jefferson River	69	88
Madison River	69	83
Gallatin River	73	85
Missouri River Headwaters	69	86
Headwaters Missouri Mainstem	81	89
Smith, Judith, & Musselshell Rivers	79	101
Sun, Teton, & Marias Rivers	76	95
Missouri Mainstem River Basin	78	98
St. Mary & Milk Rivers	80	117
Upper Yellowstone	70	88
Tongue River (Wyoming)	94	107
Lower Yellowstone	77	89

NRCS reported that, as of April 16, 2007 the snow water equivalent of mountain snowpack ranged from much below average to below average, or between 70 and 80 percent statewide for the water year, October 1, 2006 through April 16, 2007. However, total precipitation for the water year

ranged mostly from 90 to 110 percent of average as of April 16. This discrepancy can be attributed to the fact that mountain temperatures were warmer than average for the first 60 days of the water year caused the snow line to move to higher elevations resulting in rain at elevations that would normally have received snow.

As a result, much of the generous fall precipitation received in October and November 2006 occurred as rain and was not stored as water content in the mountain snowpack available for water uses during and after the normal snowmelt period in spring 2007. Nevertheless, fall mountain rainfall moistened soils and wildfire fuels, recharged groundwater, and provided generous inflow to reservoirs, especially west of the Continental Divide.

As of May 23 the snow water content of mountain snowpack currently ranges about 35 to 75 percent west of the Continental Divide, with the Kootenai River basin having snow water content of 60 percent; the Flathead River basin 77 percent; the Upper Clark Fork 53 percent; the Bitterroot 30 percent; and the Lower Clark Fork 33 percent of the 30-year average. Total precipitation received for the same period for the foregoing river basins west of the Divide ranged from 95 to 110 percent of average.

East of the Divide, the Upper Missouri River and the Missouri Main Stem basins were at 30 percent; the Lower Missouri 40; the Upper Yellowstone 30; the Tongue 52, and the Lower Yellowstone 32 percent of the 30-year average for snow water content. Unseasonably warm spells in March and again in May, with warmer than average daily high and overnight low temperatures, eroded snowpack in many areas of the state.

See: <http://www.wcc.nrcs.usda.gov/reports/SelectUpdateReport.html>

Precipitation

According to the NWS, precipitation for the period of October 1, 2006 through April 30, 2007 (water year to date) for Helena stood at 97 percent of average, Miles City was 84 percent; Billings 121 percent; Missoula 102; Kalispell 76; Ennis 130; Havre 139; Butte 108; Dillon Airport 145; Bozeman at MSU 155; Lewistown 103; Chester 185; Chouteau 125; Fort Benton 128; Great Falls 119; Glasgow 107; and Conrad 40 percent of average precipitation.

The National Weather Service Montana Weather / Precipitation for April 2007 noted that April was a month of extremes for Montana: http://www.wrh.noaa.gov/tfx/pdfs/hydro/drought_semi.pdf . Temperatures were recorded over 80 degrees and below zero on a number of occasions, but precipitation was the big story. Livingston recorded its 7th wettest April of 104-years of record keeping with 2.83 inches of precipitation.

The mountains of northwest Montana received from one to three feet of snow and up to one foot over the central part of the state from the 10th to 14th of the month. Heavy rains arrived around the 18th with well over an inch in the northwest part of the state and over two inches in central areas of the state breaking daily records at Havre, Harlem, and Shelby. By April 30, Havre received 245 percent of average; Baker 145; Billings 144; Glasgow 141; Great Falls 168; Helena 90; Cut Bank only 38; Jordan 204; Livingston 198; Wolf Point 57; Sidney 79; and Bozeman at MSU 143 percent of average precipitation for the month of April.

The USDA Crop Weather Report noted, according to the National Weather Service, that the week of April 29 brought a significant precipitation event through the southeastern part of state delivering record-breaking amounts of rain with Broadus with 4.12 inches; Ekalaka 3.08 inches; and Miles City 2.08 inches. On May 4th, Missoula, Butte, and Kalispell set new records for the day with 0.76, 0.55, and 0.84 inches. The report indicated that for the Crop Year, April 1 to May 6, the entire state was well over average, with many locations over 150 percent.

**Precipitation Statewide for Selected Time Periods
October 1, 2006 - April 30, 2007**

Division	10/1/06 - 4/30/07	4/1/06 - 4/30/07
Western	72	104
Southwest	85	125
Northcentral	98	95
Central	96	133
Southcentral	99	157
Northeast	89	111
Southeast	95	142

Soil Moisture

According to the National Climate Prediction Center (CPC), the Palmer Drought Severity Index (PDSI) for the week ending May 19, 2007 indicates the Northwest division was rated within the Mild Drought category; the Southcentral in the Incipient Drought category; the Northeast was in a Moist Spell; and the Southeast division was rated as within an Unusually Moist Spell. The Southwest, Northcentral, and Central climate divisions are rated within the Severe category. It should be noted that the PDSI is a long-term indicator of drought and tends to lag significantly for some time following a return to average or even greater than average precipitation.

**Table 2
Palmer Drought Severity Indices (PDSI) in Montana ⁽¹⁾**

District	PDSI 5/19/07	PDSI 4/1/06	Cumulative Precipitation Deficit (Inches)	
			5/19/07	4/1/06
Northwest	-1.59	2.08	1.31	0
Southwest	-3.10	-2.80	3.30	2.52
Northcentral	-3.08	-1.61	3.44	0.64
Central	-3.31	-2.68	4.10	2.33
Southcentral	-0.99	-0.75	1.38	0.56
Northeast	1.47	-0.70		0
Southeast	2.73	-0.63		0.13

Explanation: The Palmer Drought Severity Index describes the intensity of prolonged wet or dry periods as shown below. The figures are provisional and subject to change by CPC.

Range	Description
+4.0 and greater	Extremely moist spell
+3.0 through +3.99	Very moist spell
+2.0 through +2.99	Unusually moist spell
+1.0 through +1.99	Moist spell
+0.5 through +0.99	Incipient moist spell
-0.49 through +0.49	Normal
-0.5 through -0.99	Incipient Drought
-1.0 through -1.99	Mild drought
-2.0 through -2.99	Moderate drought
-3.0 through -3.99	Severe drought
-4.0 and less	Extreme drought

Notes

(1) Palmer Drought Severity Indices provided by Climate Prediction Center, Wash. D.C

The Crop Weather Report, issued by the Montana Field Office of the USDA Agricultural Statistics Service for the week ending May 21, 2007 noted that topsoil moisture in the surplus and adequate categories totaled 81 percent and subsoil moisture surplus and adequate totaled 67 percent, both close to 2006 at this time. According to the Report, topsoil moisture across the state that week was rated 2 percent very short and 17 percent short, compared with 10 and 42 percent at this time in 2006.

Topsoil is rated at 77 percent adequate and 15 percent surplus compared with 45 percent adequate and 3 percent surplus at this time last year. Subsoil moisture is rated 8 percent very short and 25 percent short, compared with 9 and 38 percent at this time in 2006. Subsoil moisture is rated as 58 percent adequate and 9 percent surplus, compared with 51 percent adequate and 2 percent surplus this date in 2006.

Winter wheat crop conditions are similar to last year at this time with none rated very poor, 3 percent poor, 21 percent fair, 43 percent good, and 33 percent excellent. Last year at this time, the winter wheat crop was rated 1 percent very poor, 10 percent poor, 35 percent fair, 40 percent good, and 14 percent excellent. According to the May 21 Crop Weather Report, range and pasture conditions are 27 percent fair, 48 percent good, and 18 percent excellent and close to 2006 at this time. The report concludes that warm weather has all crops emerging faster than last year. See: http://www.nass.usda.gov/Statistics_by_State/Montana/Publications/Crop_Progress_&_Condition/issues/2007/current_mt.pdf

Reservoir Storage

The U.S. Bureau of Reclamation reports that, as of April 1, 2007 storage at Clark Canyon Reservoir, in the headwaters of the Missouri River basin, was 85 percent of average at 126,866 acre-feet, or 118 percent of storage at this time in 2006 when contents were 107,149 acre-feet. Canyon Ferry Reservoir is currently at 109 percent of average with 1.6 million acre-feet and 125 percent of storage at this time in 2006. See (Table 3. U.S. Bureau of Reclamation Reservoirs).

As of April 1, 2007 Reclamation reports that Gibson Reservoir, located on the Sun River, had contents of 123 percent compared with 2006 at this time when it only held 34 percent of average, due to poor inflows and high demand in 2005. Sherburne Reservoir on the St. Mary River is currently at 145 percent of average storage. Sherburne supplies water from the St. Mary River Basin to the Milk River Basin water users.

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Table 3
U.S. Bureau of Reclamation Reservoirs

BUREAU OF RECLAMATION
MONTANA AREA OFFICE
RESERVOIR OPERATIONS REPORT
01-Apr-2007
ALL CONTENTS IN ACRE-FEET

RESERVOIR NAME	NORMAL FULL POOL	TOTAL CAPACITY	AVERAGE CAPACITY	RESERVOIR CONDITIONS									
				ELEVATION (FEET)		CAPACITY (ACRE-FEET)		2007				MTN. SNOW WATER CONTENT (INCHES)	
				2006	2007	2006	2007	% FULL	% OF AVG	% OF Last Yr	2006	2007	AVG
													% OF AVG
CLARK CANYON	5546.10	174,368	148,766	5531.67	5536.31	107,149	126,866	73	85	118	15.56	10.57	14.65
CANYON FERRY	3797.00	1,891,888	1,450,195	3776.52	3787.18	1,262,840	1,574,313	83	109	125	18.60	12.53	17.44
GIBSON	4724.00	96,477	47,993	4635.25	4692.29	16,251	59,000	61	123	363	11.98	9.18	12.97
PISHKUN	4370.00	46,694	34,395	4360.43	4359.56	33,269	32,199	69	94	97	N.A.	N.A.	N.A.
WILLOW CREEK	4142.00	31,848	21,925	4138.68	4140.11	27,119	29,125	91	133	107	N.A.	N.A.	N.A.
LAKE ELWELL	2993.00	925,649	675,079	2981.02	2976.23	734,061	670,141	72	99	91	19.52	15.92	20.98
SHERBURNE	4788.00	66,147	22,348	4759.08	4764.88	25,970	32,508	49	145	125	29.05	23.15	30.16
FRESNO	2575.00	92,880	53,060	2569.79	2571.28	70,218	76,137	82	143	108	N.A.	N.A.	N.A.
NELSON	2221.60	78,951	54,614	2215.57	2214.97	55,274	53,160	67	97	96	N.A.	N.A.	N.A.
BIGHORN LAKE	3640.00	1,070,029	831,066	3613.14	3609.30	823,794	798,825	75	96	97	11.46	11.32	13.83

Fresno and Nelson reservoirs on the Milk River are 143 and 97 percent of average, respectively, and 108 and 96 percent of contents last year at this time. The reservoirs are expected full pool with water users unlikely to experience shortages later in the season with normal precipitation. Lake Elwell, on the Marias River, is at 99 percent of average with a good supply outlook and should fill to within two feet of full pool by mid-June.

Lake Elwell will hopefully be able to meet the planned target release of 500 cfs to the Marias River to sustain the fishery there. The water supply outlook for Bighorn Lake on the Bighorn River is fair this year with storage of 96 percent of average as of April 1. Operations will strive to maintain a release of 2,500 cfs for the outstanding tailwater fishery below Yellowtail Dam.

As of May 2, 2007 the U.S. Geological Survey reported that water storage was above normal at two, normal at three, and below normal at one of six major hydroelectric reservoirs in Montana. Storage for April was above normal for Lake Koocanusa and Hungry Horse Reservoir. Storage was normal at Canyon Ferry, Bighorn, and Flathead Lakes, and below normal at Fort Peck Lake. Water storage was above normal at two of the four major irrigation reservoirs, Lima and Gibson reservoirs, and normal at Fresno and Clark Canyon reservoirs.

As of April 30, 18 state-owned water storage projects, 10 had contents greater than average, 4 ranged from 80 to 90 percent of average, and four projects ranged from 30 to 69 percent of average contents for April 30. See (Table 4. State-Owned Reservoirs, April 30, 2007).

Table 4
DNRC Reservoir Contents Report

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

WATER RESOURCES DIVISION - STATE WATER PROJECTS BUREAU

RESERVOIR CONTENTS REPORT

April 30, 2007

All Contents in Acre-Feet

RESERVOIR	CAPACITY*	CONTENTS				% CAPACITY	%AVERAGE	Reading Date	COMMENTS
		AVERAGE	Last Year	Last Month	PRESENT				
	Full Pool								
	Contents	1960 - 2006	4/30/2006	3/31/2007	4/30/2007	4/30/2007	4/30/2007		
ACKLEY	6,140	4,085	3,991	2,457	2,800	46	69		4/30 Estimated, 2,471AF on 4/17
BAIR	7,300	5,377	4,253	3,055	3,230	44	60	4/27/07	
CATARACT	1,478	404	442	500	430	29	106	4/30/07	3/31 Estimated
COONEY	28,230	22,764	22,430	18,784	20,531	73	90	5/1/07	
COTTONWOOD	1,900	1,563	1,900	849	1,580	83	101		4/30 Estimated
DEADMAN'S BASIN	76,900	57,867	49,401	44,176	47,222	61	82	4/25/07	
E.F. ROCK CREEK	16,040	9,256	10,000	6,990	7,681	48	83	4/30/07	
FRENCHMAN	3,752	3,542	3,752	3,752	3,752	100	106	5/1/07	
MARTINSDALE	23,348	12,097	16,056	3,501	5,263	23	44	4/27/07	
MIDDLE CREEK	10,184	6,834	6,646	7,232	8,314	82	122	4/30/07	
NEVADA CREEK	11,207	10,044	10,652	9,880	11,207	100	112	4/30/07	
NILAN	10,992	7,837	8,438	7,599	8,254	75	105	5/1/07	
N.F.K. SMITH RIVER	11,406	8,715	8,604	7,069	7,540	66	87	4/27/07	
RUBY RIVER	36,633	36,034	36,633	30,500	36,633	100	102		3/31 and 4/30 Est., 34,712AF on 4/12
TONGUE RIVER	79,071	46,705	53,329	62,149	59,716	76	128	4/30/07	
W.F. BITTERROOT	32,362	19,445	32,362	17,065	31,000	96	159		4/30 Est., Began spilling 5/4
WILLOW CREEK	18,000	17,419	18,000	17,000	18,000	100	103		3/31 and 4/30 Est., 17,402AF on 4/10
YELLOWWATER	3,842	1,218	273	127	380	10	31		4/30 Est., 319AF on 4/10, 127AF on 9/28

* Note: Reservoir contents include dead storage at the following: Ackley 325 A.F., Cooney 90 A.F., Deadman's 4,600 A.F., Nilan 900 A.F., Tongue River 711 A.F., W.F. Bitterroot 656 A.F., and Willow Creek 269 A.F..

* Note: Ruby River capacity reflects capacity at concrete crest elevation; capacity at top of flashboards is 37,612 A.F.

* Note: Middle Creek capacity reflects capacity after 1993 dam rehabilitation; prior capacity was 8,027 A.F.. Average storage shown is for post rehabilitation data.

* Note: Tongue River capacity reflects capacity after 1999 dam rehabilitation; prior capacity was 68,040 A.F.. Average storage is post rehabilitation data.

* Note: Cooney capacity reflects capacity after 1982 dam rehabilitation; prior capacity was 24,195 A.F.. Average storage shown is for post rehabilitation data.

* Note: Nevada Creek Reservoir Capacity reflects live storage capacity survey conducted in year 2000. Prior live storage capacity documented as 12,723 AF.

Streamflow

According to a May 2, 2007 Montana Water Conditions news release from the U.S. Geological Survey, monthly mean streamflow for April was normal at five, above normal at one, and below normal at two of eight long-term gauging stations. The monthly mean streamflow was below normal at the Marias River near Shelby, and at Rock Creek below Horse Creek near the International Boundary.

The monthly mean streamflow for April was normal for the Blackfoot River near Bonner, Yaak River near Troy, Clark Fork at St. Regis, the Yellowstone River at Billings, and the Middle Fork of the Flathead River near West Glacier. Discharge on the Yellowstone River at Corwin Springs was above the normal mean monthly range for April for the period of record 1971-2000. (See Table 2. April 2007 Streamflow in Montana)

Table 5 April 2007 Streamflow in Montana ⁽¹⁾			
Station Name	Monthly ⁽²⁾ Mean Flow (cfs)	1971-2000 Average Monthly Flow (cfs)	% of Average Flow
Yaak River near Troy	2,110	1,960	108
Blackfoot River near Bonner	2,030	2,140	95
Clark Fork at St. Regis	8,630	9,000	96
Middle Fork of Flathead near West Glacier	3,700	3,300	112
Marias River near Shelby	733	1,000	73
Rock Creek below Horse Creek, near International Boundary	8.01	75.4	11
Yellowstone River at Corwin	2,210	1,730	128
Yellowstone River at Billings	4,290	4,440	97

Notes: e - estimated

(1) Information is provided by the U.S. Geological Survey (USGS). According to the USGS, the eight gaging sites in Table 2 are representative of April 2007 streamflow conditions throughout Montana.

(2) Data is provisional and subject to revision.

<http://mt.water.usgs.gov/pub/nwc.release.html>

According to the USGS report before the Drought Advisory Committee on May 23, most major rivers across the state were flowing at or slightly below their period of record averages for this date. See: <http://waterdata.usgs.gov/mt/nwis/current?type=flow> With recent alternating warm and cool spells, generous valley rains and mountain snow, and premature runoff of lower than average mountain snowpack, exact reasons for current streamflow levels vary, but are sure to go down in volume sooner than normal with little remaining snow water in most headwaters basins.

According to the NRCS May 1, 2007 Montana Water Supply Outlook Report, streamflow statewide was forecasted to range from 62 to 74 statewide, including flows between 72 and 81 percent of average west of the Continental Divide and between 55 and 70 percent of average east of the Divide for the period of April through July. As was true at this time last year, May and June rains will be necessary to maintain average streamflow from late spring into early summer.

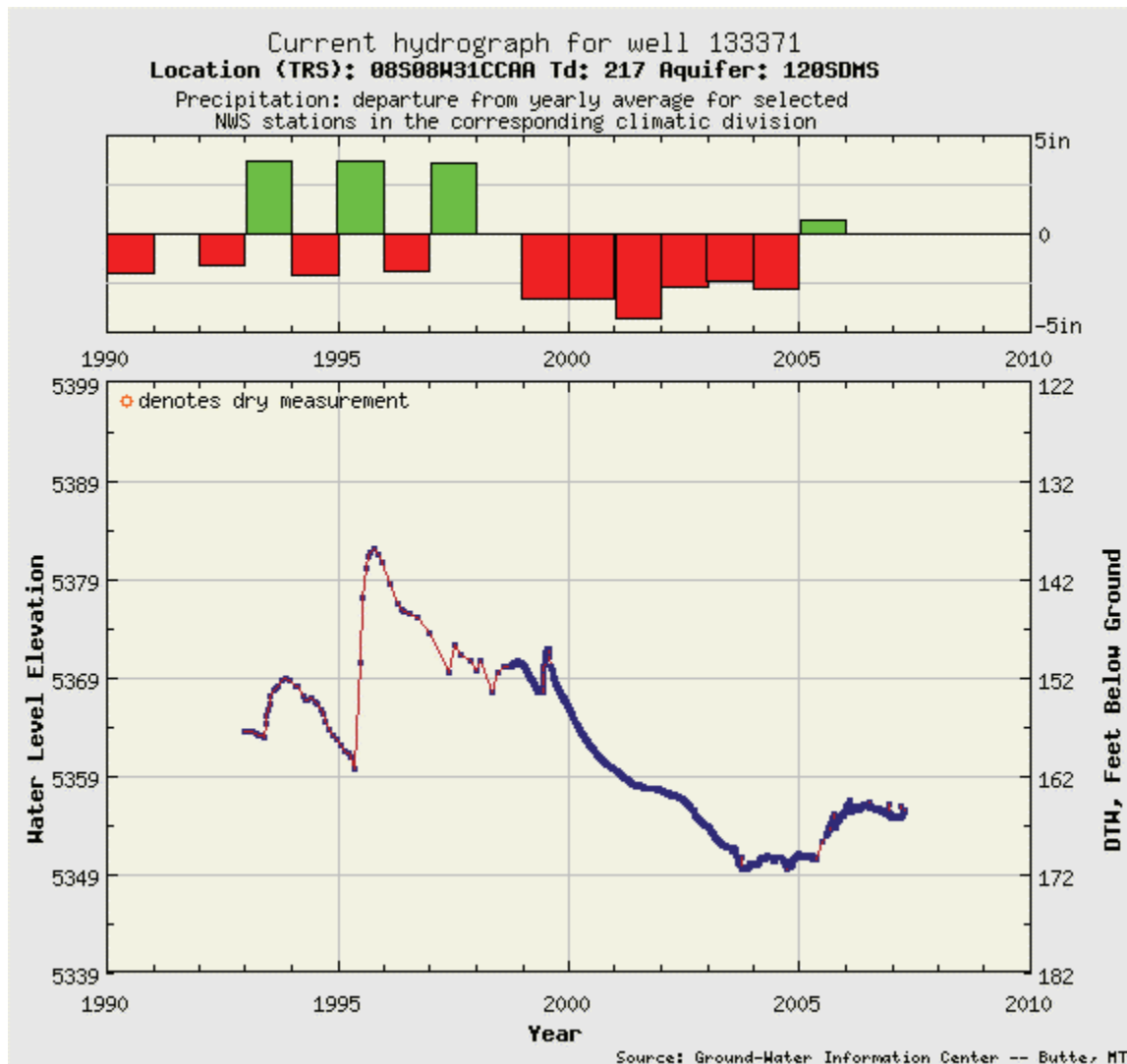
As of May 1, NRCS estimates that east of the Continental Divide, streamflow in the Missouri River Basin is expected to range from 50 to 66 percent of average; with the Jefferson to be from 37 to 55 percent of normal; the Gallatin 70 to 78 percent; and the Madison from 67 to 74 percent of average for the period of April through July. The Yellowstone River is expected to range from 63 to 75 for the period of April through July, with the upper Yellowstone ranging between 67 and 78 percent; and the lower Yellowstone between 56 and 70 percent of average streamflow.

NRCS updated its peak flow forecasts for the state on May 9. West of the Continental Divide, peak streamflow is expected to occur between May 10 and May 18, in the Missouri River basin between May 13 to May 21, and in the Yellowstone River basin from May 18 to May 26, or about 10 to 20 days earlier than normal. See: <http://www.mt.nrcs.usda.gov/snow/watersupply/peakdatetable.html>

Groundwater

The Ground-Water Assessment Program at the Montana Bureau of Mines and Geology monitors a network of about 900 wells statewide to determine groundwater level trends. Although the most recent measurements indicate that about 4 percent of fourth-quarter water levels remain more than 10 ft below their averages as of 2007, water levels in slightly more than 30 percent of the wells are only 1 to 5 ft below their averages. When drought was most intense in 2001-2003, more than 40 percent of fourth-quarter water levels were in this category and the 2006 percentage in this category was similar to that of 1999. During 2004-2006, fourth-quarter measurements from more than 10 percent of the wells were in the +1 to +5 category. It appears that fourth-quarter water levels in climate sensitive wells are responding to near average precipitation in 2005-2006 and have moved closer to their seasonal averages.

Although numerous water-level measurements from network wells show some recovery, one area east of the Continental Divide where 5-8 ft of recovery has occurred is the Blacktail Deer Creek drainage southeast of Dillon (See hydrograph well 133371 below). Water levels in these wells were relatively stable during 2006 but remain 7-10 ft below their 1993-1994 levels. The aquifer in the Blacktail Creek drainage supports extensive sprinkler irrigation. West of the Continental Divide, water levels in wells on the east side of the Kalispell Valley have recovered between 5 and 15 ft to levels similar to those observed in 1999-2000. This aquifer supports many domestic wells. Hydrographs showing water-level measurements from the statewide network are available at the Ground-Water Information Center (GWIC) at <http://mbmgwic.mtech.edu>.



Surface Water Supply Index

The NRCS generates the Surface Water Supply Index (SWSI) as a projection of surface water availability for 52 Montana river basins based on mountain snowpack, mountain and valley precipitation, streamflow, soil moisture, and reservoir storage. The SWSI is used to forecast surface water supply, and is best applied to valley areas with surface water supplies that are primarily dependent on spring runoff from high elevation mountain snowpack.

Last year at this time, the May 1, 2006 SWSI indicated 28 river basins were rated by NRCS as within the Near Average range; only 3 basins were ranked as Slightly Dry; 4 as Moderately Dry;

and one basin, Missouri River below Fort Peck, as Extremely Dry. The 13 remaining basins were rated as Slightly to Moderately Wet at that time. See: http://nris.mt.gov/Nrcs/May06/swsi05_06.pdf

As of May 1, 2007, the SWSI Map indicated that the Missouri River below Fort Peck was joined by 3 other river basins ranked as Extremely Dry. And in contrast to May 1, 2006, 16 river basins had values in the Moderately Dry category; 16 river basins in the Slightly Dry category and only 8 river basins were in the Near Average range. Three other basins were Slightly to Extremely Wet. This disparity provides a graphic illustration of the poor snow water content of the mountain snowpack of 2007 in comparison to the water content of the snowpack at this time in 2006.

See: http://nris.mt.gov/Nrcs/May07/swsi05_07.pdf

U.S. Drought Monitor

The Drought Monitor map is a widely used multi-agency, cooperative weekly assessment product that describes the degree, type, and extent of drought conditions across the nation. Montana water supply and moisture experts are consulted weekly in the national discussion regarding the data and information considered in the demarcation of areas and degree of drought impacts for Montana.

See: <http://drought.unl.edu/dm/monitor.html>

The Drought Monitor ranks the degree of drought from Abnormally Dry (D-0) to Moderate (D-1), Severe (D-2), Extreme (D-3), or Exceptional (D-4). It also distinguishes between Hydrological (long-term) and Agricultural (short-term) drought. As of May 15, The Drought Monitor showed there was no drought present over 51 percent of the state, that 49 percent of the state was in the D0 category, 18 percent the D1 category and no indication of D3 or D 4 drought. The Drought Monitor's May 12, 2007 Objective Long-term Experimental Blend map indicates three Montana climate divisions, Central, Southwest, and Southcentral, are slightly below the normal range for moisture and water supply conditions.

See: <http://www.cpc.ncep.noaa.gov/products/predictions/experimental/edb/lbfinal.gif>

The Drought Monitor's May 12, 2007 Objective Short-term Experimental Blend map indicates that two climate divisions, the southeast and northeast are above normal for moisture conditions.

See: <http://www.cpc.ncep.noaa.gov/products/predictions/experimental/edb/sbfinal.gif> The Drought Monitor's U.S. Seasonal Drought Outlook map released March 17 and valid through August 2007 calls for the likelihood of drought to persist in parts of southwest Montana.

See: http://www.cpc.ncep.noaa.gov/products/expert_assessment/season_drought.gif

Climate Forecasts

According to NOAA's National Climate Prediction Center (CPC) the 30-day outlook issued April 30 shows that there is a 40 percent chance of above average precipitation expected for the month of May across Montana: http://www.cpc.ncep.noaa.gov/products/predictions/30day/off_mon_prctp.gif

According to the Climate Prediction Center (CPC) 3-month long lead outlook maps, the period of May-June-July has equal chances of normal, below normal, or above normal precipitation (33 percent) and temperatures with the exception of the eastern one-third of the state which is expected to be 33- to 40-percent cooler than normal. At this time, the 3-month long-lead June, July, August outlook calls for temperatures to be normal across the state with the exception of the eastern one quarter, and for precipitation to be average.

See: http://www.cpc.ncep.noaa.gov/products/predictions/long_range/lead02/off_index.html

Temperature and precipitation long-lead outlooks from CPC are generally favorable or neutral until the July-August-September map when between a 33- and 37-percent chance of drier than normal conditions and a 33- to 40-percent chance of warmer than normal conditions are forecast for that three-month period for most of the state except the eastern one-third with equal chances of above, below, or normal conditions.

See: http://www.cpc.ncep.noaa.gov/products/predictions/long_range/lead03/off_index.html

The El Nino / Southern Oscillation (ENSO) climate anomaly status, which is determined by a sea surface temperature (SST) monitoring network in a zone bounded by 120W and 170W Longitude and 5N and 5S latitude, indicates that as of May 15, the tropical Pacific is in an ENSO-neutral state following cooler SSTs in February of 2006. A majority of the ENSO climate models now indicate and are in agreement that SST anomalies will become increasingly negative during the next three months. If the foregoing trend continues as predicted, La Nina conditions could develop over the course of summer 2007. ENSO has a more reliable signal for winter than summer months in the region of Montana, but if the anomaly was strong enough could mean a higher percentage probability of cooler than average temperatures and above average precipitation for Montana.

Wildfire Potential

It is early to formulate a detailed assessment of wildfire danger for the coming season in Montana due to the size and diversity of fuels and early season conditions across the state. Spring usually brings more grassland wildfire activity than larger forest fires which tend to occur during summer and fall. DNRC's Northern Rockies Coordination (NRCC) Center, is an integrated multi-agency wildfire coordination entity that brings together fire potential intelligence for Northern Idaho, North Dakota, much of South Dakota, Yellowstone Park, and Montana and is located in Missoula. A DNRC representative of NRCC holds a seat on the Drought Committee and reports monthly at its meetings. The public can access wildfire information for the state and region at the Internet addresses below and through the Governor's Drought Advisory Committee web site.

See: http://gacc.nifc.gov/nrcc/predictive/outlooks/monthly_outlook.pdf

Montana DNRC is reporting 27 human and lightning caused wildfires which have burned 178 acres as of May 11, 2007. The fires were reported from the Northwestern, Southwestern, and Central region land offices. The Northern Rockies Coordination Center (NRCC) Monthly Fire Weather / Fire Danger Outlook for May 2007 reports 1000-hour dead fuel moisture levels are normal to slightly below normal on the plains at 15-22% and in the mountains at 17-26%.

Wildfire season fire outlooks can be found at: <http://gacc.nifc.gov/nrcc/index.htm> and <http://gacc.nifc.gov/nrcc/predictive/outlooks/outlooks.htm>

CONCLUSION

At this time consensus of experts on the Montana Governor's Drought Advisory Committee is that *Hydrological Drought* is certain to present drought impacts for surface water uses, such as irrigation, and for instream uses, such as fishery and aquatic life support, and recreation, by early summer. The extent and severity of impact from the forecasted short supply of surface water will vary based upon precipitation received locally, length of daylight hours during periods of high air temperature daily highs and lows, water demand, and the extent of snow water shortfall of particular river basins. Some areas of the state may still suffer from low aquifer levels and this situation will further exacerbate low streamflow in certain river basins. The potential for drought through early July is therefore rated as ***Moderate***, which corresponds with the Committee's Drought Status by County map index and the *Drought Alert* level for the state.

Steady improvement of soil moisture at valley elevations from precipitation over the course of the 2007 Water Year (October 1, 2006 to date) and generous mountain rainfall in the first two months of the water year and in spring, have resulted in favorable outlooks for impact expected from *Agricultural Drought* and neutral and favorable climate forecasts for the degree of *Meteorological Drought*. Additionally, the *Socio-Economic* aspects of drought look the most favorable in years for agricultural producers, with fair to good moisture for crops and favorable markets for meat, livestock, grains, and other crops. The Committee's Internet site includes the data sources used by the Committee as well as complete meeting information with detailed reports of the member agencies for viewing. See: <http://drought.mt.gov/committee/meetings.asp>

RESPONSES TO WATER SUPPLY AND MOISTURE CONDITIONS

Support for Watershed Groups and Local Drought Committees

Watershed groups across the state have worked hard over the course of the drought bringing stakeholder groups together to coordinate planning for drought. Drought Committee member agencies DNRC and Fish, Wildlife and Parks continue to supply technical, data, and funding support for watershed and local drought planning groups. The Departments of Environmental Quality, Agriculture, Livestock, and Commerce provide information support to assist constituents in coping with impacts during drought. Once again, drought impacts are expected in Montana. The projected surface water supply for summer 2007 is forecast to fall short of demand by July due to significant shortfalls of snow water content in the mountain snowpack of many watersheds of the state, particularly east of the Continental Divide.

DNRC hydrologists, engineers, and planners work closely with watershed groups, irrigation and canal companies, and individual water users to improve irrigation and water conveyance efficiency and to maintain and rehabilitate water storage projects. DNRC's Water Management and Water Operations bureaus provide water measurement support to assist watershed groups in the implementation of water use and drought plans. For example, in late 2006, DNRC Drought Committee staff assisted the Big Hole Watershed Group and the U.S. Fish and Wildlife Service in acquiring a dozen water measurement instruments and 10 steel water flumes to prepare for drought plan implementation for the 2007 and future water use seasons.

DNRC hydrologists continue to work with water users and partner agencies in the Upper Big Hole River to implement the new Candidate Conservation Agreement with Assurances (CCAA) for protection of the fluvial arctic grayling. The CCAA will create site-specific conservation plans with landowners to improve irrigation delivery and efficiency, grazing management, and riparian protection. In return, landowners are provided assurances that protect them from further regulatory enforcement should the grayling get listed as an endangered species.

The National Integrated Drought Information System (NIDIS)

In 2006 a bill was passed by Congress calling for the establishment of the National Integrated Drought Information System (NIDIS). NIDIS will pull together a myriad of existing sources of real-time water supply and climate data analysis and forecasting capabilities into a system to support informed decision-making at all levels of government, enabling water users and resource managers to assess risk from drought to their businesses, farms and ranches, and other areas of vulnerability. Montanans stand to benefit from NIDIS because the system will increase the resolution of moisture data over vast areas otherwise cost prohibitive to equip with adequate instrumentation coverage. NIDIS will also facilitate those most directly affected by drought with more specific decision-making guidance.

Significant progress has been made with the implementation of NIDIS under the leadership of National Oceanic and Atmospheric Administration (NOAA) in partnership with the Western Governor's Association. Drought Committee staff attended a 2-day conference in 2006 along with representatives of three other states with progressive drought management programs to provide the perspective of end-users and to further explore the NIDIS concept. Montana and a variety of stakeholder agencies and organizations continue to be involved with NIDIS in the development of drought impact forecast and mitigation products.

Livestock Assistance

On September 15, 2006, Montana was one of 20 states that received block grants for livestock producers with losses due to drought. Montana received \$933,433 in federal assistance through the USDA. Montana Department of Agriculture, with assistance from Montana State University Extension Service, worked quickly to get affected producers signed up for the program so that they were able to receive checks by the end of December. Livestock producers with documented damage in Big Horn, Carbon, Carter, Custer, Fallon, Powder River, and Rosebud counties were eligible for the drought disaster funding.

USDA Natural Disaster Determination (NDD)

In 2006, 24 Montana counties and one tribal nation were designated as primary NDD counties by the USDA Farm Service Agency. Most of the counties were located in southeastern, southcentral, and central Montana. As primary NDD counties, drought affected producers are eligible for low interest emergency loans, and a deferral on federal taxes prompted by the forced sale of livestock due to the effects of drought. The U.S. Small Business Administration again followed suit with USDA making owners of businesses in primary NDD counties directly tied to agriculture eligible for low interest loans as well. Many small businesses in outlying counties have suffered or have been liquidated over the course of six consecutive years of drought.

Science-based Initiatives

Drought Committee staff has recently volunteered on behalf of Montana to participate as a reviewer and eventually, an end-user of a new program referred to as VegDRI. VegDri is designed to be used as a more accurate method of assessing crop conditions and the presence of drought. The project is in a pilot study phase at this time and is currently asking participants to reconcile actual conditions on the ground with the maps generated on a weekly basis. Periodic feedback from experts (e.g., state climatologists, US Drought Monitor authors, and agricultural experts), agricultural producers, and others in the general public will be used to characterize the general strengths and weaknesses of VegDRI and highlight specific locations or trends that might be in error. The current VegDRI model is based on historical climate and satellite observations for a 16-year period spanning from 1989 to 2005. Prime examples are the extreme drought conditions throughout much of the Central U.S. in 2002 and the extremely moist spell in 1993 experienced by much of the U.S. See: http://drought.unl.edu/vegdiri/VegDRI_EvalInst.htm

Climate Change

According to the U.S. Geological Survey and other credible authorities including NOAA, areas of the Western U.S. dependent upon mountain snowpack for annual water supplies can expect to see more of what has occurred over the course of the past 10 years – spring snowmelt period occurring 2 to 4 weeks earlier than the historical record. This trend obviously has great implications for water uses, and water dependent aquatic life support systems. The challenge of meeting demand for surface water uses during the summer season is likely to be greater than ever in Montana.

Also apparent for some time have been the effects that climate anomalies such as El Nino and its reverse counterpart, La Nina can have on our region. The El Nino Southern Oscillation (ENSO) or the cyclical cooling and warming of sea surface temperatures, in what is known as the equatorial Pacific Nino 3.4 Region, can have a significant effect upon the occurrence and severity of drought over Montana and the Pacific Northwest. In response to indications that ENSO may tend to increase in frequency, the Montana's State Office of Climatology, in partnership with the University of Montana's Numerical Terradynamic Simulation Group, has started exploring the ability to forecast the relationship of ENSO to the frequency of occurrence and severity of wet and dry conditions in Montana. See: <http://climate.ntsg.umt.edu/>

The University of Montana's Numerical Terradynamic Simulation Group is a lab pioneering new approaches for addressing regional ecological problems using remote sensing and geographic information systems. Accordingly, the Group is comparing historical Montana climate records with recent trends in an attempt to project likely scenarios for future climate trends in Montana. The group is making use of microclimate maps which improve snowmelt, runoff, drought, and flooding projections. See: <http://www.ntsg.umt.edu/>

In December 2005 Governor Schweitzer established the Governor's Climate Change Advisory Committee. The Committee was established with the aim of formulating recommendations for specific actions for reducing or sequestering greenhouse gas emissions. The Committee will also identify opportunities to promote energy efficient technologies and clean, renewable energy resources that will enhance economic growth. Climate change may mean more severe storms and droughts affecting crop production, pests and growth rates. See: <http://www.mtclimatechange.us/>

Internet Site

The Montana State Library's Natural Resources Information System (NRIS) continues to provide support to the Drought Committee for maintaining important parts of its Internet site, including current links to the NRCS SWSI map suite and archives, the U.S. Drought Monitor and its related products, and all support for Montana Drought Status Map. Montana DNRC maintains all other content of the Governor's Drought Advisory Committee Internet site. See: <http://drought.mt.gov>

Reclamation States Emergency Drought Relief Assistance Act

The Bureau of Reclamation is authorized to provide funding assistance under the Reclamation States Emergency Drought Relief Act, Public Law 102-250 (The Act), to mitigate effects of drought upon wetlands, rivers and streams, reservoirs, and municipal water supplies. Eligible projects include temporary construction projects that manage limited supplies of water and wells for municipal and drought management purposes. The Act is not a grant program. Reclamation contracts with the businesses for the work to be performed and provides project oversight and monitoring.

Reclamation approved three water conservation and management project applications under the Act in 2006-2007. A proposal from the Big Hole Watershed Committee for the acquisition of 10 flume structures for water measurement, for a total of \$10,000, was approved to implement the drought plan in the Upper Big Hole Watershed. Additionally, two applications for the drilling of up to 16 livestock water wells in the Upper Big Hole were approved by Reclamation. The wells are being used as part of a conjunctive use plan whereby water right holders forgo the diversion of streamflow, switching to the wells as a source of livestock water during the annual period of low streamflow to preserve instream flow for aquatic life stressed during drought. Montana DNRC hydrologists provide technical support to the watershed group by designing and maintaining the watershed gauging network and monitoring and reporting streamflow on a regular basis over the course of the water use season. The U.S. Fish and Wildlife Service received \$50,000, and the Big Hole Watershed Committee received \$19,500 for conjunctive use livestock water wells.

The implementation of the surface water provisions of the Big Hole Drought Plan is part of a larger multi-agency initiative to facilitate and support recovery of the threatened riverine arctic grayling population in the Big Hole River Basin, which has a history of streamflow drought impacts exacerbated by heavy summer water use for irrigation. Since 1999, the watershed group has made great strides in bringing together local and area stakeholders to find solutions to improve instream flow during summer with private, state, and federal technical and funding support. DNRC Water Management Bureau, serving as staff for the Governor's Drought Advisory Committee, coordinated the application process for the aforementioned projects with the Bureau of Reclamation and the applicants.

In 2004, DNRC Drought Committee staff was successful in receiving approval from Reclamation under the Act for 13 applications by water user groups and canal companies for a total of \$104,000 for use in sealing leaking canals or ditches with a biodegradable sealant applied by spraying. In 2005, Reclamation denied approval for about 30 such proposals from water user groups and canal companies totaling about \$300,000. Several of the groups that applied the sealant reported measured and documented water savings during 2004. Due to concerns about potential toxicity of the canal sealant product, Reclamation commissioned a study in cooperation with the Desert Research Institute in Reno, Nevada. In early 2007, Reclamation announced that the studies were inconclusive and remaining uncertainty regarding the toxicity of sealant products precluded it from approving new sealant application proposals indefinitely.

A number of small towns received assistance from Reclamation for municipal water supply problems over the period 2002-2006, including Circle, Sage Creek Colony, Ulm School, Pine Creek School, Hobson, Ryegate, Geraldine, Roy, Melstone, Galata, Shelby, Fairfield, Ingomar, and Forsyth. Reclamation continues to work to attain closure with one or two of the water supply assistance applicant communities. Requests and questions for Reclamation's Drought Relief Program can be directed to Mr. Jess Aber at Montana Department of Natural Resources and Conservation at (406) 444-6628.

Drought Advisory Committee Meetings

For 2007, the committee will next meet June 14 to assess and report conditions heading into the 2007 growing season. Future meetings for 2007 are scheduled for July 19, August 16, September 19, and October 11th. April and October meetings are mandated by the statute regardless of conditions at the time.

The committee will continue to monitor and report conditions closely and issue the Montana Drought Status Map, by county, on a monthly basis. Staff will continue to provide support to Montanans in locating sources of assistance for projects that serve to mitigate impacts during future drought years. Staff will also continue to work toward changes in national drought policy that serve to benefit Montana.

MAP FIGURES

Montana Drought Status by County
May 1, 2007

<http://nris.state.mt.us/Drought/status/>

NRCS Montana Surface Water Supply Index May 1, 2007

http://nris.mt.gov/Nrcs/May07/swsi05_07.pdf

U.S. Drought Monitor Map May 22, 2007

<http://drought.unl.edu/dm/monitor.html>

U.S. Seasonal Drought Outlook Map (CPC)

http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html

Palmer Drought Severity Index – May 19, 2007

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer.gif

Montana Precipitation – Water Year through April 30, 2007

http://www.wrh.noaa.gov/tfx/image.php?wfo=txf&type=data2&loc=hydro&path=hydro&fx=watyr_pcntnorm.png

Montana Precipitation – Calendar Year 2007

http://www.wrh.noaa.gov/tfx/image.php?wfo=txf&type=data2&loc=hydro&path=hydro&fx=calyr_pcntnorm.png

Montana Monthly Precipitation –April 2007

<http://www.wrh.noaa.gov/tfx/dbgraphs.php?wfo=txf&loc=monthly&fx=aprpcentnorm.png>

APPENDIX

Drought Statute

In 1991, Montana's Fifty-second Legislature passed House Bill 537, creating a state drought advisory committee and defining its responsibilities. The law states:

The Drought Advisory Committee shall submit a report to the governor describing the potential for drought in the coming year. If the potential for drought merits additional activity by the drought advisory committee, the report must also describe:

- (a) Activities to be taken by the drought advisory committee for informing the public about the potential for drought;
- (b) A schedule for completing activities;
- (c) Geographic areas for which the creation of local drought advisory committees will be suggested to local governments and citizens; and
- (d) Requests for the use of any available state resources that may be necessary to prevent or minimize drought impacts (Section 2-15-3308 MCA 1991).

Types of Drought

As the Montana Governor's Drought Advisory Committee continues to assess the current protracted cycle of drought, it is instructive to consider the different types of drought, as assessments vary depending upon type and duration of drought. In this regard, the National Drought Mitigation Center, located at the University of Nebraska, Lincoln, has prepared the following narrative:

What is Drought?

(National Drought Mitigation Center: <http://www.drought.unl.edu/whatis/concept.htm>)

Understanding and Defining Drought

The Concept of Drought

Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration; it differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate.

Drought is an insidious hazard of nature. Although it has scores of definitions, it originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. Drought should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration (i.e., evaporation + transpiration) in a particular area, a condition often perceived as "normal." It is also related to the timing (i.e., principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness (i.e., rainfall intensity, number of rainfall events) of the rains. Other climatic factors such as high temperature, high wind, and low relative humidity are often associated with it in many regions of the world and can significantly aggravate its severity.

Drought should not be viewed as merely a physical phenomenon or natural event. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply. Human beings often exacerbate the impact of drought. Recent droughts in both developing and developed countries and the resulting economic and environmental impacts and personal hardships have underscored the vulnerability of all societies to this "natural" hazard.

Conceptual Definitions of Drought

Conceptual definitions, formulated in general terms, help people understand the concept of drought. For example: Drought is a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield.

Operational Definitions of Drought

Operational definitions help people identify the beginning, end, and degree of severity of a drought. (An abbreviated description of operational definitions is also available.) To determine the beginning of drought, operational definitions specify the degree of departure from the average of precipitation or some other climatic variable over some time period. This is usually done by comparing the current situation to the historical average, often based on a 30-year period of record. The threshold identified as the beginning of a drought (e.g., 75 percent or less of average precipitation over a specified time period) is usually established somewhat arbitrarily, rather than on the basis of its precise relationship to specific impacts.

An operational definition for agriculture might compare daily precipitation values to transpiration rates to determine the rate of soil moisture depletion. This relationship can then be expressed in terms of drought effects on plant behavior (i.e., growth and yield) at various stages of crop development. A definition such as this one could be used in an operational assessment of drought severity and impacts by tracking meteorological variables, soil moisture, and crop conditions during the growing season, continually reevaluating the potential impact of these conditions on final yield. Operational definitions can also be used to analyze drought frequency, severity, and duration for a given historical period. Such definitions, however, require weather data on hourly, daily, monthly, or other time scales and, possibly, impact data (e.g., crop yield), depending on the nature of the definition being applied. Developing climatology of drought for a region provides a greater understanding of its characteristics and the probability of recurrence at various levels of severity. Information of this type is extremely beneficial in the development of response and mitigation strategies and preparedness plans.

Disciplinary Perspectives on Drought:

Meteorological, Hydrological, Agricultural and Socioeconomic

Meteorological Drought

Meteorological drought is defined usually on the basis of the degree of dryness, when compared to some "normal" or average amount of precipitation and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. For example, some definitions of meteorological drought identify periods of drought on the basis of the number of days with precipitation less than some specified threshold. This measure is only appropriate for regions characterized by a year-round precipitation regime such as a tropical rainforest, humid subtropical climate, or humid mid-latitude climate. Other definitions may relate actual precipitation departures to average amounts on monthly, seasonal, or annual time scales.

Agricultural Drought

Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapo-transpiration, soil water deficits, reduced ground water or reservoir levels, and so forth. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought should be able to account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity. Deficient topsoil moisture at

planting may hinder germination, leading to low plant populations and a reduction of final yield. However, if topsoil moisture is sufficient for early growth requirements, deficiencies in subsoil moisture at this early stage may not affect final yield if subsoil moisture is replenished as the growing season progresses or if rainfall meets plant water needs.

Hydrological Drought

Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, ground water). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with, or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and ground water and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. For example, a precipitation deficiency may result in a rapid depletion of soil moisture that is almost immediately discernible to agriculturalists, but the impact of this deficiency on reservoir levels may not affect hydroelectric power production or recreational uses for many months. Also, water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., flood control, irrigation, recreation, navigation, hydropower, wildlife habitat), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.

Socioeconomic Drought

Socioeconomic Drought reflects the societal impacts of drought on existing economic and social systems and communities. Hydrological and Socioeconomic drought are related in that they tend to demonstrate the long-term effects of drought. And although they are the last group of impacts to take hold following the onset of drought, they are the longest lasting of the four types of drought and can linger for years following the beginning of recovery from the meteorological and agricultural, or short-term aspects of drought. Impacts include strain on the solvency of businesses in the agricultural service sector, such as trucks, heavy equipment, feeds and fertilizer, custom harvesting, and fuel as well as the small businesses that support agricultural communities. Debt also affects the ability of concerns to endure and some will fail never to be re-established. Human impacts can include depression, anxiety, substance abuse, domestic abuse, and gambling.

